

1    **Claims**

2

- 3    1.    An apparatus comprising a first chamber and a  
4           second chamber and a membrane which divides  
5           the first and second chambers; the membrane  
6           comprising a support and a catalyst;  
7           the membrane being adapted to allow passage of  
8           a first reactant from the first chamber to the  
9           second chamber through said membrane;  
10          wherein the first reactant is imparted with  
11          enough energy by the catalyst upon said  
12          passage so as to react with the second  
13          reactant.
- 14
- 15    2.    Apparatus as claimed in claim 1, wherein the  
16          support is adapted to operate at temperatures  
17          exceeding 250°C.
- 18
- 19    3.    Apparatus as claimed in claim 2, wherein the  
20          support comprises an inorganic support.
- 21
- 22    4.    Apparatus as claimed in any preceding claim,  
23          wherein the support comprises pores and there  
24          is a gradation in the average pore radii  
25          towards one surface of the support.
- 26
- 27    5.    Apparatus as claimed in any preceding claim,  
28          wherein the membrane is adapted to activate  
29          molecules of the first reactant without  
30          forming an ionic species before the reaction  
31          with the second reactant.

32

- 1    6.    Apparatus as claimed in any preceding claim,  
2        wherein the support comprises a layer with a  
3        roughened surface which has an increased  
4        tortuosity compared to the tortuosity of the  
5        rest of the support.  
6
- 7    7.    Apparatus as claimed in claim 6, wherein the  
8        relatively roughened surface is provided on an  
9        outer surface of the support.  
10
- 11
- 12   8.    Apparatus as claimed in any preceding claim,  
13        wherein a flux control layer is provided on  
14        the support.  
15
- 16   9.    An apparatus as claimed in any one of claims 6  
17        or 7, wherein a flux control layer is provided  
18        on a first surface of the support and the  
19        layer with a roughened surface is provided on  
20        an opposite surface of the support.  
21
- 22   10.   Apparatus as claimed in claim 8 or 9, wherein  
23        the flux control layer comprises an inorganic  
24        porous layer which is adapted to hold a  
25        portion of the catalyst therein and to control  
26        the passage of the first reactant through the  
27        membrane.  
28
- 29   11.   Apparatus as claimed in any one of claims 8 to  
30        10, wherein the flux control layer is selected  
31        from the group consisting of silica and gamma  
32        alumina.

- 1 12. Apparatus as claimed in any preceding claim,  
2 wherein the catalyst comprises a metal  
3 catalyst.  
4
- 5 13. Apparatus as claimed in claim 12, wherein the  
6 metal catalyst is selected from the group  
7 consisting of rhodium, ruthenium and nickel.  
8
- 9 14. Apparatus as claimed in any preceding claim,  
10 wherein the membrane is provided in the shape  
11 of a cylinder.  
12
- 13 15. Apparatus as claimed in any preceding claim,  
14 wherein the membrane comprises one or more  
15 struts.  
16
- 17 16. Apparatus as claimed in any preceding claim,  
18 wherein the support comprises alpha alumina.  
19
- 20 17. A method of producing hydrogen gas, the method  
21 comprising:  
22 providing a membrane, the membrane comprising  
23 a support and a catalyst;  
24 passing a first reactant through the membrane  
25 from a first chamber to a second chamber;  
26 allowing the first reactant to come into  
27 contact with the catalyst upon passage through  
28 said membrane;  
29 imparting the first reactant with enough  
30 energy so as to react with the second  
31 reactant;

- 1            reacting the first reactant with a second  
2            reactant to produce hydrogen gas.  
3
- 4    18.    A method as claimed in claim 17, wherein the  
5            energy imparted on the first reactant  
6            activates molecules of the first reactant  
7            without forming an ionic species before the  
8            reaction with the second reactant.  
9
- 10   19.    A method as claimed in claim 17 or 18, wherein  
11            the temperature is over 500°C.  
12
- 13   20.    A method as claimed in claim 19, wherein the  
14            temperature is between 700°C and 800°C.  
15
- 16   21.    A method as claimed in any one of claims 17 to  
17            20, wherein the first reactant is one of  
18            oxygen and a hydrocarbon, and the second  
19            reactant is the other of oxygen and a  
20            hydrocarbon.  
21
- 22   22.    A method as claimed in claim 21, wherein the  
23            oxygen and hydrocarbon do not come into  
24            contact with each other until the first  
25            reactant has passed through said membrane from  
26            the first chamber to the second chamber.  
27
- 28   23.    A method as claimed in claim 21 or 22, wherein  
29            the hydrocarbon comprises a normally gaseous  
30            hydrocarbon.  
31

- 1    24.    A method as claimed in any one of claims 20 to  
2            23, wherein the pressure within the first  
3            chamber is greater than the pressure within  
4            the second chamber.  
5
- 6    25.    A method as claimed in any one of claims 20 to  
7            24, wherein carbon monoxide is formed in  
8            addition to the hydrogen.  
9
- 10   26.    A method as claimed in claim 25, wherein the  
11           carbon monoxide and hydrogen are further  
12           reacted to produce normally liquid  
13           hydrocarbons in a Fischer-Tropsch type  
14           reaction.  
15
- 16   27.    A method as claimed in any one of claims 20 to  
17           25, wherein the hydrogen is recovered for use  
18           as a fuel.  
19
- 20   28.    A method of preparing a membrane, the method  
21           comprising:  
22           providing a support; and  
23           adding a catalyst to the support.  
24
- 25   29.    A method as claimed in claim 28, wherein the  
26           support is an inorganic support.  
27
- 28   30.    A method as claimed in claim 28 or 29, further  
29           including the step of applying a coating to  
30           one of the surfaces of the support.  
31

- 1 31. A method as claimed in claim 30, wherein the  
2 coating produces a roughened surface on the  
3 support, said surface having an increased  
4 tortuosity compared to the tortuosity of the  
5 rest of the support.  
6
- 7 32. A method as claimed in claim 30 or claim 31,  
8 wherein the coating comprises a metal oxide or  
9 metal oxide precursor.  
10
- 11 33. A method as claimed in claim 32, wherein the  
12 metal oxide or precursor comprises a group IV  
13 metal oxide or group IV metal oxide precursor.  
14
- 15 34. A method as claimed in claim 33, wherein the  
16 group IV metal oxide or precursor comprises  
17  $\text{TiO}_2$  or a  $\text{TiO}_2$  precursor.  
18
- 19 35. A method as claimed in claim 30, wherein the  
20 coating produces a flux control layer on the  
21 membrane.  
22
- 23 36. A method as claimed in any one of claims 30 to  
24 34, wherein a second coating, the second  
25 coating being a flux control layer, is also  
26 applied to the support.  
27
- 28 37. A method as claimed in claim 35 or 36, wherein  
29 the flux control layer is applied to the  
30 membrane by exposure to a boemite sol.  
31

1 38. A method as claimed in any one of claims 28 to  
2 36 wherein the coating and/or the second  
3 coating is applied by dipping the support into  
4 a liquid comprising the coating.  
5

6 39. A method as claimed in any one claims 28 to  
7 38, including the step of applying the  
8 catalyst to a surface of the membrane by  
9 passing a catalyst precursor solution over a  
10 first surface of the support and an osmotic  
11 solution over the opposite surface of the  
12 support, and allowing the catalyst or a  
13 catalyst precursor to be deposited on the  
14 support via the process of osmosis.  
15

16 40. A method as claimed in any one of claims 28 to  
17 39, further including the steps of drying the  
18 support and heating/firing the support.  
19